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ABSTRACT

We measure the impact of municipal policies requiring governments to construct green buildings on private-sector adoption of the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) standard. Using matching methods, panel data, and instrumental variables, we find that government procurement rules produce spillover effects that stimulate both private-sector adoption of the LEED standard and supplier investments in green building expertise. Our findings suggest that government procurement policies can accelerate the diffusion of new environmental standards that require coordinated complementary investments by various types of private adopter.

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Governments often use their formidable purchasing power to promote environmental policy objectives. In the U.S., federal and many state agencies have incorporated environmental attributes in their procurement policies for decades, and government green procurement policies are especially prevalent in Europe where they are promoted by the European Commission.[1] The U.S. Environmental Protection Agency (EPA) and the European Union, for example, have developed environmentally preferable purchasing guidelines for goods ranging from paint, paper, and cleaning supplies to lumber and electricity; many state and local governments have taken similar steps (e.g., Clinton 1998; National Association of State Procurement Officials 2010; Commission of the European Communities 2008). Some government green procurement policies have focused on government buildings, spurred in part by their substantial aggregate energy consumption (Coggburn and Rahm 2005, Commission of the European Communities 2008). Several U.S. states and a growing number of municipalities have also implemented green building procurement policies, most of which refer to the LEED standard (Environmental Law Institute 2008; Rainwater 2009). Because government purchases account for 10-15 percent of GDP in developed countries, government procurement policies can substantially bolster demand for targeted goods and services.

Beyond directly increasing government-sector demand, some public procurement policies seek to spur private demand (Marron 2003) or to spark cost-reducing innovation among suppliers (Brander et al. 2003). The European Union, for example, justifies its environmental procurement policy not only on the basis of leveraging government demand to "create or enlarge markets for environmentally friendly products and services" but also on the basis of stimulating "the use of green standards in private procurement" (Commission of the European Communities 2008: 2). Similarly, an Organisation for Economic Co-operation and Development (OECD) conference on greener public purchasing noted that government green procurement policies can not only bring about direct environmental benefits through government purchases, but "perhaps more significantly" could encourage "the private sector to improve the environmental characteristics of their own procurement strategies" and thereby indirectly elicit "the development, commercialization and diffusion of less environmentally-damaging products and services."[2] This

[1] For more on government procurement as a policy instrument, see Coggburn and Rahm (2005), Commission of the European Communities (2008), McCrudden (2008); Michelsen and de Boer (2009), and National Association of State Procurement Officials and Responsible Purchasing Network (2010).
[2] Quoted from a "Summary of Proceedings of Workshop on 'Budget, Financial & Accounting Issues in Greener Public

study is, to our knowledge, the first to investigate whether or not public procurement policies actually generate these spillover effects.

We examine whether municipal green building procurement policies that apply *only* to municipal buildings accelerate the use of green building practices by private-sector developers, as manifested by more rapid diffusion of the U.S. Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) standard for sustainable building practices. We find that the LEED standard diffuses nearly twice as quickly among private-sector developers in municipalities that adopt government-oriented green building procurement policies, when compared to a matched control sample of cities of similar size, demographics, and environmental preferences (e.g., citizen support for environmental ballot initiatives, Toyota Prius vehicle ownership rates). We also show that the impact of these green building procurement policies does not stop at the city line. In particular, we find more LEED adoption among "neighbor cities"—those bordering a city that adopted a green building policy—compared to these neighboring cities' own set of matched controls. This neighboring-city effect suggests that our estimates capture actual spillovers, rather than unobserved regulatory or political factors that might drive both public and private procurement within a city.

To explain the link between public green procurement policies and the diffusion of the LEED standard among private developers, we consider three mechanisms that could explain our main results. First, government procurement policies might stimulate local private-sector demand for green buildings by raising awareness, potentially legitimating a particular standard. Second, government procurement might encourage the development of complementary input markets. For example, if more architects, contractors, and consultants invest in green building skills and credentials, a combination of learning-curve effects and increased competition could drive down the cost of developing a LEED-certified building. Thirdly, there might be a coordination failure in the market for green buildings, whereby developers are waiting for key suppliers to invest in LEED expertise while those same suppliers are waiting for evidence of ample demand from developers. In the case of green buildings, municipal government procurement policies might

Purchasing,'" organized by the OECD Environment Directorate and the Austrian Ministry of Agriculture, Forestry, Environment and Water Management, Vienna, October 29-30, 2001 (Johnstone 2003: 225-235).

jump-start the development of specialized input markets by providing a guaranteed demand for LEED-accredited professionals and other suppliers, thereby reducing their risk of investing in LEED-specific capabilities.

We find no empirical support for the first two mechanisms described above, but do find some evidence that supports the third option (i.e., overcoming "excess inertia" in the creation of a LEED standard). First, we compare the effects of procurement policies across cities with varying taste for green products. We find no evidence that procurement policies had a greater impact in greener cities, which suggests that our estimates are not driven by an interaction between general awareness of the LEED standard and latent demand for green buildings. Second, we allow the effects of green building procurement policies to vary with city size. If procurement policies mainly lower the price of private LEED certification by helping local suppliers reach efficient scale (and consequently promoting price competition), these policies should have a greater impact in small cities where specialized input markets should be less mature. In practice, we find stronger policy effects in larger cities, suggesting that procurement policies do more than just stimulate entry into the green building labor market. Finally, we use instrumental variables to measure the causal impact of LEED Accredited Professionals[3] on private developers' LEED adoption rates and vice versa. There can only be coordination failures in LEED adoption if both effects are positive, which we find to be the case.[4]

Overall, our findings suggest that government purchasing policies can break deadlocks that emerge when coordinated investments are required to adopt a common standard and that this stimulates the private-sector market for the goods and services targeted by government green procurement policies.

Related literature.—Our study contributes to three broad literature streams. First, we add to a nascent literature that characterizes how governments are increasingly incorporating

[3] Architects, contractors, consultants, suppliers, and others can learn about LEED and pass a test to earn the title of "LEED Accredited Professional."

[4] To estimate the impact of an increase in LEED Accredited Professionals on private developers' LEED adoption rates, we use green building policy adoption in distant cities as an instrument for LEED Accredited Professionals in nearby cities. To show that private developers' LEED adoption rates cause an increase in the supply of LEED Accredited Professionals, we use new construction starts (conditional on city size) to instrument for the level of LEED adoption.

environmental criteria into their procurement policies. Much of this work is descriptive. For example, Coggburn and Rahm (2005) and May and Koski (2007) describe the emergence of green building procurement policies within the U.S. federal and state governments. McCrudden (2004) provides an historical context by recounting how governments have used procurement policies to promote a host of social objectives. Michelsen and de Boer (2009) and Sourani and Sohail (2011) identify barriers to implementing green building procurement policies and capabilities that can overcome them. Marron (1997) and Marron (2003) describe the potential impacts of government green procurement policies.

We also contribute to a second literature that examines the adoption and impact of green building practices. Eichholtz, Kok, and Quigley (2010) provide the first large-scale evidence of private benefits from green building, using building-level data to show that green-certified properties have higher rents and occupancy rates than comparable properties in the same neighborhood. Kok and Jennen (2012) report similar results. Kahn and Vaughn (2009) show that LEED certification and Toyota Prius ownership were highly concentrated in wealthy coastal areas. Kok, McGraw, and Quigley (2011) find that the LEED and Energy Star green building certification programs have diffused rapidly across U.S. cities; their study revealed a positive association between the supply of LEED Accredited Professionals and the growth rate of LEED certification.

Unlike prior studies of LEED diffusion, ours focuses on spillovers from public procurement rules to private adoption. Choi (2010) finds greater commercial LEED adoption in cities with municipal policies that provide formal administrative benefits, such as quicker review cycles for green building proposals, or that mandate commercial buildings to incorporate green features. We provide evidence of spillover effects on private real estate development even when municipal green building procurement policies *do not* provide explicit rules or incentives to encourage private adoption.

Our study also contributes to the broad literature on quality certification. While this literature typically emphasizes information problems (see Dranove and Jin (2010) for a review), we focus on the role of network effects in the diffusion of a new standard. When the success of a new quality standard depends on many different actors (such as producers, wholesalers, retailers, and customers), certification programs will resemble a multi-sided platform, with adoption by one group conferring an externality on the others. Farrell and Saloner (1986) model technology adoption in the presence of network effects and coin the term "excess inertia" to describe the familiar chicken-and-egg coordination problem whereby each side waits for the others to adopt. Corts (2010) applies a two-sided platform perspective to study the diffusion of alternative fuels and shows that government procurement of "flex fuel" vehicles that run on both gasoline and ethanol led to increased supply of ethanol at local filling stations. We follow Corts by measuring the impact of government procurement policies on the supply of complements, which in our setting is the number of LEED-accredited real estate professionals (e.g., architects and general contractors). We extend his analysis by measuring the impact of government procurement policies on private adoption of the *same* goods and services and by evaluating a broader range of potential mechanisms. Our results suggest that government procurement rules helped the LEED standard overcome excess inertia in local real estate markets.

Finally, by examining the efficacy of government procurement, we contribute to a growing literature evaluating alternative regulatory approaches such as voluntary programs and agreements (e.g., Delmas and Montes-Sancho 2010; Toffel and Short 2011) and mandatory information disclosure programs (e.g., Jin and Leslie 2003; Weil et al. 2006; Bennear and Olmstead 2008; Kim and Lyon 2011; Doshi, Dowell, and Toffel 2012). With procurement becoming an increasingly popular policy instrument (National Association of State Procurement Officials and Responsible Purchasing Network 2010; Commission of the European Communities 2008), our research confirms the promise of this approach, at least in the context of green building. More research is needed to reveal the conditions under which such policies are most likely to be effective and to understand potential unintended consequences.

The balance of the paper is organized as follows: Section I outlines a simple framework for analyzing the impact of green building procurement policies on the private sector and describes the LEED standard. Section II describes our data, measures, and empirical methods. Section III describes the empirical results. Section IV offers concluding remarks.

I. Public Procurement and Environmental Standards: Theory and Institutions

A. *Procurement Spillovers in Theory*

Government purchasing guidelines often use price preferences or quantity targets (typically called set-asides) to reward products that meet environmental criteria such as incorporating recycled content, exhibiting pollution levels well below regulatory limits, or exceeding voluntary energy efficiency standards. These policies can significantly boost demand for the targeted products and services through the government's own procurement decisions, especially when the government is a major customer. However, the impact of these procurement policies may extend beyond this direct effect, depending on how government purchasing interacts with private-sector procurement.[5] In practice, governments often try to capitalize on this potential by designing policies that they hope will "influence the behavior of other socio-economic actors by setting the example, and by sending clear signals to the market-place" (Organisation for Economic Co-operation and Development 2000: 20).[6]

In principle, government procurement policies can influence private-sector purchasing through supply channels, demand channels, or both. Moreover, the private-sector response to a government green purchasing policy might either reinforce or counteract that policy's direct impacts.[7]

Supply Channels.—On the supply side, government green procurement policies can stimulate private-sector demand for the targeted products and services when increased government purchases reduce suppliers' average costs, such as when there are significant scale economies or learning-curve effects in key input markets.[8] When fixed costs are large relative to the size of the

[5] Marron (2003) estimates that government purchases account for less than 20 percent of expenditures in *all* nondefense product categories.

[6] For example, a stated objective of the Massachusetts environmental purchasing policy governing the state's agencies was to "encourage manufacturers and service providers to incorporate environmental and sustainability considerations into their products and operations locally, nationally, and even globally" (Patrick 2009). Similarly, one of the priorities of the United Kingdom government's "sustainable procurement" initiative is "stimulating the market to develop more sustainable solutions" (United Kingdom Office of Government Commerce 2010).

[7] Donald Marron (2003) provides a general analysis and discussion of green public purchasing.

[8] For instance, many military technologies require substantial up-front R&D expenditures and rely on the scale economies produced by military procurement programs to reach cost levels that are suitable for civilian application. This theory is closely related to the "induced innovation" hypothesis that procurement preferences lead to increased competition and innovation on the targeted product or service attributes. For example, Siemens (2003) suggests that a preference for the Energy Star label in

market, government purchases might also spur entry, leading to more competition and lower prices (Bresnahan and Reiss 1991).

An alternative theory of positive procurement spillovers is that explicit government preference for a particular product or standard will help private market participants overcome excess inertia in the adoption process. By stimulating the supply of goods that meet a particular standard, government demand can provide a focal point for private demand. This theory assumes that private suppliers and customers cannot independently internalize the benefits of a more coordinated supply chain, perhaps because of the risk that prior investments in specific standards and systems will be stranded or underutilized.[9] For example, the U.S. Department of Agriculture's (USDA) organic certification program was developed partly in response to concerns that farmers and consumers were confused by a proliferation of competing private organic labels and could not coordinate on a common standard (Fetter and Caswell 2002).

In principle, government procurement policies could also have negative spillovers that stifle private consumption. When supply is inelastic, for example, government procurement rules might reduce private purchases of the targeted goods through the well-known mechanism of "crowding out" (Marron 1997).[10] Alternatively, if procurement rules define a sharp cutoff between green and brown products, the private supply of environmental goods might become concentrated just above the green-compliance threshold. If some suppliers would have produced greener products in the absence of a sharp cutoff, then environmental procurement rules could actually reduce the supply of green goods, even as they increase compliance by some firms.[11]

Demand Channels.—Government procurement policies might also produce a shift in the private demand curve, as opposed to movement along it. For example, procurement policies could

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government computer purchasing led to increased innovation in energy-efficient electronics.

[9] Rochet and Tirole (2006) show that a similar coordination failure as the central assumption in the literature on multi-sided platforms.

[10] While we could find no clear examples of crowding out in green procurement, there is some evidence that the supply of green power is inelastic, so government subsidies for green electricity are primarily spent on marketing and advertising these higher-priced services to end consumers, as opposed to investing in new generation facilities (Rader 1998).

[11] This seems especially likely when procurement policies are based on voluntary standards developed by firms with strong incentives to preempt more stringent regulation (Lyon and Maxwell 1999; King and Lenox 2000; Reid and Toffel 2009). Interestingly, this suggests that government purchasing policies should sometimes avoid specifying particular private standards, especially when there are questions about the motives of the developers of those standards or about the stringency of the private certification.

increase the visibility or credibility of a green product (or label) to private consumers, especially when consumers are unable to evaluate claimed environmental benefits on their own. Put differently, procurement policies might unleash latent demand for green goods simply by raising consumer awareness. We expect these information-based demand-side effects to be most salient when the green product or label has minimal market share, so awareness is relatively low.

Government procurement rules could also influence private demand by altering the weight that consumers attach to specific policy priorities. For instance, a government could exercise moral suasion, leading private firms and consumers to follow its purchasing guidelines, if those parties are already favorably disposed towards the underlying policy goals. On the other hand, public procurement might crowd out private demand if consumers come to perceive that the public sector is already "doing enough" to support those same goals.

Government Green Building Procurement Policies.— In practice, the importance of any supply- and demand-side channel depends on specific features of that product's market. There are several reasons to expect that, in our analysis, private demand will respond positively to government green building procurement policies. First, government is an especially large customer in the real estate market. With 26.3 percent of all spending on "maintenance and repair construction" coming from federal, state, and local government (Marron 2003), this industry's share of total government purchases is second only to that of munitions. Second, builders can realize direct benefits from green investments that produce energy savings or that increase tenants' willingness to pay (Eichholtz, Kok, and Quigley 2010). Third, our analysis covers a period when LEED was just emerging as the dominant standard for green building certification (see Figure 1), so government procurement policies could plausibly jump-start key input markets if suppliers were waiting on private developers to commit to a standard. While each of these factors suggests that we should observe a positive correlation between government green building procurement policies and private-sector green building certification, they also suggest that we should be cautious about extrapolating our findings to settings with mature standards and technologies, few direct benefits, or a small share of government purchases.

B. *LEED Certification and Accreditation*

LEED is a green building certification program developed and administered by the nonprofit USGBC. Started in 1998, LEED initially focused on rating the environmental attributes of new construction and has since added rating schemes for commercial and retail interior design, residences, neighborhoods, and building renovation.

LEED awards points for incorporating specific design elements or meeting environmental performance targets in eight categories: location and planning, sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, innovation and design, and regional priority. All certified projects must achieve a minimum number of points in each category; more total points qualify projects for increasingly prestigious certification levels: certified, silver, gold, and platinum.

The LEED certification process begins with the developer registering a project with USGBC, which "serves as a declaration of intent to certify" the building, provides the developer access to LEED information and tools, and lists the project in the publicly available online LEED project database (Green Building Certification Institute 2011). Once the construction or renovations have been completed and the certification application is submitted, reviewed, and approved, the applicant is sent a plaque (often displayed in the lobby in commercial buildings) and the project is included in the online LEED database of certified projects.

The cost of adopting the building practices necessary to obtain LEED certification varies by the type and scale of project and by the certification level. Costs accrue by coordinating the required design elements and using more expensive materials and technologies. The activities required to achieve LEED points range from relatively cheap (such as installing bike racks) to quite expensive (remediating a brown-field site). The administrative costs of LEED certification are small by comparison, amounting to roughly $450-600 to register a project with USGBC and an additional $2,000 certification fee. Some developers hire a consultant to provide guidance on the LEED-eligibility of particular design choices and procurement decisions and to prepare the LEED application.

The benefits of LEED can accrue from increased rents and occupancy rates and from reduced operating costs. Several studies have found that LEED-certified buildings charge a 3-5 percent rent premium and have higher sale prices and occupancy rates (Chegut, Eichholtz, and Kok 2012; Eichholtz, Kok, and Quigley 2010, forthcoming; Fuerst and McAllister 2011a, 2011b). Evidence of reduced operating costs is mixed, in part because LEED certification emphasizes design elements rather than energy consumption. Engineering studies suggest that LEED certification is correlated with increased energy efficiency (Turner and Frankel 2008; Newsham, Mancini, and Birt 2009; Sabapathy et al. 2010). For example, engineering estimates from a study of 121 LEED-certified projects that volunteered data on energy use suggest that these buildings consume 25-30 percent less energy than the national average for comparable projects (Turner and Frankel 2008), though others have raised concerns that some LEED-certified buildings do not deliver energy savings (Navarro 2009).

The LEED certification system debuted in 1998 but did not achieve significant scale until the second half of the 2000s. Figure 1 shows the number of new LEED registrations per year from 2000 to 2007. This figure reached 1,000 in 2005 and jumped to 4,000 in 2007 (the peak of the real estate cycle).[12] LEED's growth reflects several factors, including increased awareness of the program, a growing installed base of LEED Accredited Professionals, and the creation of new LEED certification programs for building categories such as homes and renovations. Figure 1 also shows that federal, state, and local governments have been significant LEED adopters since the program began.

C. Empirical Roadmap

Our analysis of LEED diffusion builds on the idea that the standard resembles a multi-sided platform that facilitates interactions among real-estate developers and suppliers of green-building inputs (e.g., professional services or building materials). Thus, our first set of empirical results measures the strength of "same side" spillovers in LEED adoption between government and private developers.[13] Specifically, we find a positive relationship between the adoption of

[12] The LEED-registered project directory (www.usgbc.org/LEED/Project/RegisteredProjectList.aspx) shows that registrations continued to accelerate in 2008 and 2009 even as the overall market for commercial real estate markets cooled off.

[13] We borrow the "same side" terminology from the literature on multi-sided platforms to denote an externality between two

government green building procurement policies and the number of LEED-registered private-sector buildings. This relationship could exist for a variety of reasons, including demonstration effects, moral suasion, scale economies, learning effects, anticipated regulatory changes, and a correlation between municipal green building policies and preferential treatment in the municipal permitting process for developers offering green buildings. We attempt to rule out several of these explanations by examining whether or not green building procurement policies have a greater impact in larger or greener cities and by measuring the policies' impact on private developers in neighboring cities, who would benefit from spillovers produced by a focal city's green building policy but would not, for example, receive preferential treatment in its permitting process.

Our second set of empirical results measures the strength of "cross-side" spillovers in LEED adoption between developers and building-industry professionals.[14] As with any platform, a larger installed base on one side should generate an increased supply of complements on the other. We show that government green building procurement policies stimulate investment in green building expertise among local real estate professionals (measured as the number of LEED Accredited Professionals). In principle, real estate professionals might invest in this green building know-how without any government encouragement or formal certification program if they expected this human capital to be rewarded in the marketplace. However, uncertainty about whether and how the market will observe, measure, and reward green building creates a possibility of stranded investment and thus an opportunity for government procurement spillovers.

While our analysis of "cross-side" spillovers examines the impact on LEED-accredited real estate professionals, we expect government green building procurement policies to jump-start a host of complementary input markets. For instance, producers and local distributors of building materials might be more likely to carry products that meet LEED criteria after a green building procurement policy is adopted. Viewing the number of LEED Accredited Professionals as a proxy for a host of specialized green inputs helps clarify why developers might be slow to adopt

groups of users that do not transact with one another but typically use a standard or platform in a similar way.

[14] In the literature on multi-sided platforms, a "cross-side effect" is a positive externality between two groups that use a platform to interact with one another, such as video game players and video game developers.

LEED even if they believed there is latent demand for green buildings: the cumulative expense of being a green first-mover could be large, even if contractors and architects constitute a small share of total construction costs.

In our final set of analyses, we switch from measuring the reduced form impacts of government green procurement policies to measuring the structural links between each side of the LEED platform. In particular, we estimate the causal impact of LEED Accredited Professionals on private-sector LEED registrations by using "distant" green procurement policies as an instrumental variable. The key maintained assumption in this analysis is that municipal green procurement policies in far-away cities increase the supply of LEED Accredited Professionals in nearby markets, but are otherwise excluded from the LEED adoption decisions of private developers in a focal market. To estimate the causal impact of LEED Registrations on LEED Accredited Professionals, we use the number of new buildings constructed between 2003 and 2007 (conditional on city size) as an instrument for Registrations. We find that both of these structural relationships are positive, which supports the theory that government procurement policies may promote LEED diffusion by helping real-estate developers and building-industry professionals overcome "excess inertia" in the early stages of the adoption process.

II. Data and Measures

To assess the impact of municipal green building procurement policies on private-sector adoption of LEED-certified green building practices, we collected data on 735 California cities from 2001 to 2008. We selected California primarily because it is the state with the largest number of municipal green building policies. Our dataset combines information from a variety of sources. We obtained LEED diffusion data from the USGBC, nonresidential construction starts data from McGraw Hill, and city-level demographic data from the U.S. Census; we hand-collected data on the municipal adoption of green building policies. Summary statistics are presented in Table 1.

We use two main outcome variables to measure the diffusion of LEED within the private sector and one variable to measure government LEED adoption. All of our outcomes are based on data obtained from the USGBC. Our unit of analysis is the city (or city-year), where we define cities in terms of a Census Place, the geographical unit with available Census demographics and voting records data that most closely resembles the political unit of a municipality.

LEED Registrations—Annual Private LEED Registrations is an annual count of new privately owned nonresidential or multi-unit residential buildings that registered for LEED certification. This number reflects private-sector developers' intention to use green building practices.[15] *Total Private LEED Registrations* is the total (cumulative) number of *Annual Private LEED Registrations* for each city during our sample period of 2001 to 2008. This total ranged from 0 to 99 across all the cities in our estimation sample (which excludes Los Angeles, San Francisco, San Diego, and San Jose).[16] On average, there were two new LEED-registered buildings in a city in our sample over this time period.

We also created a count of *Annual Government LEED Registrations* to verify that municipal government green procurement policies actually lead to an increase in government LEED procurement. This variable is a count of new nonresidential structures that are owned by a local government and that were registered for LEED certification. *Total Government LEED Registrations* is each city's total number of *Annual Government LEED Registrations* from 2001 to 2008. The cities in our sample registered a total of 0 and 12 new government buildings, with an average of 0.3 LEED-registered buildings per city between 2001 and 2008.

LEED Accredited Professionals—Our second outcome measure captures LEED-specific human capital investments by local real estate professionals. *Annual LEED Accredited Professionals* is the annual number of building industry professionals (such as architects, contractors, and consultants) who passed the USGBC's LEED accreditation exam between 2001 and 2008. This exam certifies that such professionals have knowledge of green building practices in general and

[15] LEED registration is only the first step towards certification. The USGBC encourages projects to register early, since many decisions that will influence certification levels must be taken at early stages of the development process. Because the lag from registration to certification can be several years and the LEED standard was diffusing rapidly toward the end of our sample period, a count of certified buildings would have excluded a large number of projects in our data set. For the buildings for which we have certification data, the average lag between registration and certification is between two and three years. Anecdotal evidence suggests that few registered buildings fail to certify at some level. A drawback of relying on the number of LEED registrations or of LEED certifications is that they do not contain any information on the environmental impact of certification, a topic we leave to future research.

[16] We exclude the four largest cities in California when calculating these summary statistics, since they (a) could not be matched for the analysis below and (b) tend to distort the sample averages due to their extreme size.

the LEED standard in particular. In 2004, it cost roughly $350 to take this test. *Total LEED Accredited Professionals* is the total number of *Annual LEED Accredited Professionals* from 2001 to 2008. We obtained the city locations of LEED Accredited Professionals from their business addresses maintained in the USGBC directory of LEED Accredited Professionals. By 2008, there were between 0 and 416 such professionals in each city in our estimation sample, with an average of 7.5 per city.

Government Procurement Policies—Our main explanatory variables indicate whether or not a focal city (or a city that borders a focal city) had adopted a municipal green building policy targeting only government buildings by the current calendar year. We gathered this policy information by hand, starting from lists compiled by the USGBC and the U.S. Department of Energy-funded Database of State Incentives for Renewables and Efficiency (DSIRE).[17] We identified 155 U.S. cities that had adopted some type of green building ordinance by 2008. Forty were in California, though we exclude from our analysis seven cities whose regulations impose green building mandates on private-sector development. (The municipal green building procurement policy adopter cities in California are listed in the Appendix.)

Municipal green building policies vary along several dimensions, including the types of structure affected (by size, owner, and use); whether they cover only new buildings or also renovations; and how they measure environmental performance. We gathered details on each policy from city websites and the online library of municipal codes.[18] Our research indicates that 87 percent of all green building polices contained a purchasing rule—that is, a requirement that new public projects adhere to some type of environmental standard—and that 90 percent of these rules specified the LEED standard.

For cross-sectional models, we create a time-invariant indicator variable, *Green Policy Adopter*, that equals 1 if a city had adopted a green procurement policy by 2008 and equals 0 otherwise. For panel data models, we create a time-varying indicator variable, *Green Policy Adopted*, coded

[17] We acknowledge the excellent research assistance provided by Mark Stout. The DSIRE list of state and local incentives is available at http://www.dsireusa.org/ and the USGBC list can be found at http://www.usgbc.org/PublicPolicy/SearchPublicPolicies.aspx?PageID=1776 .

[18] Available at www.municode.com.

1 starting the year a city adopted a green procurement policy and 0 before that. Similarly, for the neighboring city analysis, we create (a) a time-invariant indicator, *Green Policy Adopter Neighbor*, that equals 1 for cities that had not adopted a green procurement policy but bordered a city that had done so by 2008, and equals 0 otherwise, and (b) a time-varying indictor variable, *Green Policy Adopted Neighbor*, coded 1 for cities that had not adopted a green procurement policy but bordered a city that had done so by the focal year, and coded 0 otherwise. Four percent of the cities in our estimation sample had adopted a municipal green building policy by 2008 and 15 percent of the cities in our sample are green policy adopter neighbors. While our matching procedure (described below) excludes Los Angeles, San Francisco, San Diego, and San Jose from the analysis of procurement policy adopters, each of these cities does in fact adopt a green building procurement policy, and therefore provides variation in the treatment condition used in the neighbor city analysis.

Construction Activity—To control for variation in the underlying rate of new building activity, we purchased data on new building starts from McGraw Hill's Dodge Construction Reports. The control variable *Total New Buildings* is a cumulative count of nonresidential construction starts between 2003 and 2007 (the years we could afford to purchase). The mean number of new nonresidential construction starts for a city in our estimation sample from 2003 to 2007 was 26.21. Since this variable is highly skewed and strongly correlated with city population (ρ = 0.88), we also calculated the number of new *Buildings per Capita*.

Demographics—For each city in the analysis, we obtained *Population* (measured in units of 10,000), *Income* (median household income in $10,000s), and *College* (the share of adults with some college education) at the Census-Place level from the 2000 U.S. Census.

Environmental Preferences—We collected several measures of a city's prevailing preference for environmental sustainability. First, we gathered data on citizens' political preferences by calculating *Green Ballot Share* as the proportion of citizens' votes in favor of statewide ballot initiatives addressing environmental quality (Kahn 2002; Wu and Cutter 2011). Using data from University of California's Statewide Database (http://swdb.berkeley.edu/), we calculated the proportion of votes in favor of various environmental ballot initiatives during 1996-2000 within the Census Place that best corresponded to each city. These ballot initiatives received support from an average of 61 percent of each city's citizenry.

Second, we obtained data on green purchasing behaviors by calculating the proportion of vehicles registered in 2008 that were Toyota Priuses, based on ZIP-code-level vehicle registration data from RL Polk (Kahn and Vaughn 2009; Kahn 2011). We aggregate these registration data to the city level to reflect the Prius market share in each city, creating the variable *Prius Share*, which has a mean of 0.54 percent.[19]

Finally, using data from the League of Conservation Voters (LCV), we calculated the proportion of pro-environment votes on environment-related bills cast by each city's delegates to the California State Senate and House of Representatives. These variables, *LCV Senate Score* and *LCV House Score,* range from 0 (for cities whose delegates voted against all environmental-related bills) to 100 (for cities whose delegates voted in favor of all such bills), with an average near 50 for both the House and Senate across all cities in our estimation sample.

III. Analysis and Results

A. *Matching and Balance*

To generate unbiased estimates of the causal impact of government green building procurement policies on private-sector LEED registrations and LEED-accredited professionals, we construct a matched sample using the Coarsened Exact Matching (CEM) procedure developed by Iacus, King, and Porro (2012). This approach assumes that, after stratifying and reweighting the data to account for the distribution of observed exogenous variables, the endogenous treatment variables (*Green Policy Adopter* and *Green Policy Adopter Neighbor*) are as good as randomly assigned. Intuitively, CEM is just a method of preprocessing a dataset before running a weighted least-squares regression. One begins by "coarsening" (discretizing) the variables in order to construct a multi-dimensional histogram. The next step is to discard observations from any cell that does not contain both treated and control observations. Finally, the units are weighted such that a

[19] The highest Prius registration rate is 3.74 percent in Portola Valley (just west of Palo Alto).

weight of 1 is assigned to each treated unit, and a weight of T_i/C_i is assigned to each control observation in cell *i* (where T_i and C_i are the number of treatment and control observations, respectively, in the *i*-th stratum of the multi-dimensional histogram). Weighted least-squares estimation then yields an estimate of the treatment effect for treated cities.

Iacus, King, and Porro (2012) describe several advantages of CEM over the propensity score and other matching techniques. Unlike conventional regression control methods, CEM does not extrapolate counterfactual outcomes to regions of the parameter space where there are no data on controls. Because CEM is non-parametric, there is no possibility that a mis-specified model of selection will produce greater imbalance in variables that are omitted from the matching procedure, which can happen with the propensity score. Moreover, CEM ensures that the reweighted control sample matches *all* of the sample moments of the treated sample, not just the means.[20] Finally, Monte Carlo tests and comparisons to experimental data suggest that CEM outperforms alternative matching estimators that rely on the same fundamental assumption of exogenous treatment conditional on observables.

We use CEM to construct two matched samples: one consisting of green policy adopters and their quasi-control group and another consisting of green policy adopter neighbors and their quasi-control group. In both cases, our goal is to achieve balance—statistically indistinguishable distributions between the treatments and controls—across a set of exogenous covariates that might lead to policy adoption, including environmental preferences (measured with *Prius Share*, *Green Ballot Share*, *LCV Senate Score*, and *LCV House Score*), market size and growth (*Population*, *Total New Buildings*, and *Buildings per Capita*), and income and education (*Income* and *College*).

For the green policy adopters, we match on *Population* and *Prius Share*, which yields a matched sample consisting of 26 adopters and 180 controls. When coarsening *Population*, we create 10 strata.[21] This results in a very close match on the size distribution, but leads to a curse of dimensionality (that is, very small samples) if we include many additional variables in the match.

[20] This property of CEM proved important in our application, where the city-size distribution is highly skewed

[21] We set cut points at 10, 50, 70, 100, 120, 150, 250, 300, 350, and 470 thousand inhabitants, and omit cities above the top threshold because there are no suitable controls.

So, for the policy adopter cities, we add only *Prius Share*, with cut points at the 25th, 50th, 75th, 90th, and 95th percentiles.[22] Because the green policy neighbors sample is somewhat larger, we also match on *Income*, *Green Ballot Share*, and *LCV Senate Score*. However, to prevent a substantial drop in sample size, we use a very coarse match for these additional variables.[23] Our final estimation sample for the neighbor city contains 80 green policy neighbors and 291 matched control cities. *Green Policy Adopter* cities are not used as potential controls for the sample of *Green Policy Adopter Neighbors*.

Table 2 illustrates how CEM dramatically improves the balance in the means of exogenous covariates across the treatment and control samples. Each row in the table reports means for the treatment and control cities in a particular sample and a t-statistic from regressing each covariate on the treatment dummy (*Green Policy Adopter* or *Green Policy Adopter Neighbor*). Panel A of Table 2 compares all cities that adopt a green building policy, excluding the four largest, to the full set of potential controls (that is, to all other cities in California) using unweighted OLS regressions.[24] Not surprisingly, we find that cities adopting a green building policy are larger, greener, wealthier, and better educated than the potential controls. There is a statistically significant difference in the means of each variable except for the per-capita measure of new construction activity.

Panel B of Table 2 compares CEM-weighted means for the matched sample of green policy adopters and their controls. Note that matching on *Population* and *Prius Share* excludes three cities (Oakland, Berkeley, and Ventura) from the treatment group, reducing it to just 25 green building procurement policy adopters. Since we used the distributions of *Population* and *Prius Share* to construct the match, by construction we should observe no difference in the means of these variables across treatment and control cities. In fact, Panel B of Table 2 shows that matching on just these two dimensions eliminates the statistical significance of differences in the

[22] In terms of actual registration rates, the corresponding values are 0.5, 0.8, 1.0, 1.5, and 2.7 percent of all registered vehicles.

[23] For the neighbor-city matching, we leave the *Population* cut points unchanged. We continue to use the 25th, 50th, 75th, 90th, and 95th percentiles of *Prius Share*, which correspond to registration rates of 0.26, 0.56, 1.21, 1.78, and 2.36 percent of all vehicles. Finally, we set cut points at the 25th and 75th percentiles of *Income* ($44 and $70 thousand) and at the medians of *Green Ballot Share* (67 percent approval) and *LCV Senate Score* (44 points).

[24] Each of the four largest cities in California (Los Angeles, San Diego, San Jose, and San Francisco) has adopted a green building procurement policy. Including these cities in the analysis leads to a dramatic increase in imbalance and a similarly large increase in the results presented below.

means of all observables across the matched adopters and non-adopters.

Panel C of Table 2 compares means for green policy neighboring cities and their matched controls. Once again, CEM matching and reweighting removes differences in the means of the exogenous covariates. Though we do not show raw comparisons for green policy neighbor cities, they are also larger, greener, wealthier, and better educated than the potential controls. As in Panel A, the raw means of all variables are statistically significantly different across green policy neighbor cities and the potential controls. For this sample, matching removes 31 green policy neighbor cities and 324 potential controls.

B. *Preliminary Graphical Analysis*

Figure 2 illustrates how the CEM-weighted means of our two main outcome variables (*Private LEED Registrations* and *LEED Accredited Professionals*) evolved in green policy adopters and their neighboring cities relative to their matched controls from 2002 to 2008. All four bar graphs in Figure 2 illustrate the same rapid acceleration in LEED diffusion that we observed in Figure 1. And in all four cases, the effect is more pronounced for green policy adopters (or their neighbors) than for the relevant matched and weighted control samples.[25] We also observe a small "bump" in LEED Accredited Professionals for both treated and control cities in 2004, which was likely driven by anticipated changes in the USGBC exam that increased the costs of becoming a LEED Accredited Professional.

The following sections use cross-sectional and panel regression to explore whether the differences in the patterns observed for treatment and control cities in Figure 2 are statistically significant. After finding that they do differ significantly, we use instrumental variables to estimate the causal relationships between *Total Private LEED Registrations* and *Total LEED Accredited Professionals* and we use interaction effects to investigate particular mechanisms that might drive the procurement policy effects.

[25] These patterns are even more striking if we do not use the CEM weights, since there are relatively more small cities in the matched control samples and the weighting procedure makes these small markets less important.

C. *Cross-sectional Analysis*

Cross-sectional Model—We begin our empirical analysis with a cross-sectional comparison of cumulative LEED adoption in the matched green policy adopters and control cities.[26] The Coarsened Exact Matching procedure described above creates a matched group of treatment and control cities that are balanced with respect to all of the observable covariates we associate with policy adoption. Under the assumption that assignment to the treatment group is independent of potential outcomes conditional on observables, a simple t-test is sufficient to estimate the causal impact of the green building procurement policy. Since adding controls might lead to increased precision, we use OLS regression instead of a t-test.[27] Specifically, we estimate the following linear regression:

(1) $$Y_i = \alpha_i + \beta \cdot GreenPolicy_i + \boldsymbol{\gamma} \cdot X_i + \varepsilon_i \, ,$$

where Y_i is either *Total Government LEED Registrations*, *Total Private LEED Registrations*, or *Total LEED Accredited Professionals* in city *i* as of 2008. X_i represents a set of controls for factors potentially associated with LEED adoption: environmental preferences (*Prius Share*, *Green Ballot Share*, *LCV Senate Score*, and *LCV House Score*), market size and economic growth (*Population*, *New Buildings*, and *Buildings per Capita*), educational attainment (*College*), and wealth (*Income*).

As described above, the city-size and demographic variables were obtained from the 2000 Census, Prius registration data are from 2008, and the green ballot share is averaged over 1996-2000. We are interested in the coefficient β, which measures the difference in LEED adoption between *Green Policy Adopter* cities and their matched controls (or alternatively, between *Green Policy Adopter Neighbors* and their matched control cities).

Cross-sectional Results—We estimate this cross-sectional model using CEM-weighted OLS regressions.[28] The results are presented in the Panel A of Table 3. Columns 1-3 report estimates from weighted OLS regressions that compare CEM-matched green policy adopters to their

[26] The cross section is based on data through 2008.

[27] It should be emphasized, however, that we do not use the control variables to extrapolate potential outcomes to regions of the parameter space where there are very few treated or untreated units.

[28] As stressed in Angrist and Pischke (2009), OLS provides the best linear approximation to the conditional expectation function, even though Y_i is a count variable. Estimating a model with an exponential conditional expectation function (i.e., Poisson with a robust covariance matrix) produces similar results.

control cities.

Our estimates of the spillover effects of government procurement on private-sector demand are found in Column 1. We find a statistically significant increase of 7.5 private LEED registrations in cities with a green building policy. Since the weighted mean of private LEED registrations is 8.3, this estimate is a 90-percent increase in LEED adoption. The results in Column 2 show that government green procurement policies—as intended—spur greater municipal green building. We find an average of 1.6 more government LEED registrations in cities adopting a green building procurement policy. While this is not surprising given that 90 percent of these policies use LEED as the relevant yardstick, it is nevertheless reassuring to see a large and statistically significant direct impact. Column 3 shows an increase of 15.7 LEED Accredited Professionals in green policy adopting cities relative to their matched controls. This is an increase of roughly 38 percent beyond the weighted mean of 40.8, but is not statistically significant. This result is statistically weaker than the private LEED registration result (Column 1) partly because real estate professionals are often based in surrounding communities, an issue we discuss in detail below.

Panel B in Table 3 shows that our estimates change very little if the CEM weights are dropped from the OLS regression. We also found that the CEM-weighted results are robust to dropping various groups of control variables and that the estimated treatment effect increases significantly if we drop both the CEM weights and the regression controls or if we ignore the matching procedure (results not reported).

Columns 4-6 in Table 3 focus on cities that border a green policy adopter. These models estimate the effect of a green building policy on green policy neighbors compared to the effect on their matched controls. We examine the policy impact on neighboring cities for three reasons. First, the neighboring city sample might address lingering concerns about omitted variables (for example, tastes for green-ness) that could influence both policy adoption and private-sector LEED building rates. Second, the neighbors provide a larger and more representative sample of "treated" cities. Finally, and perhaps most importantly, the presence or absence of neighboring-city effects tells us something about the underlying mechanism that links government green procurement policies to private-sector adoption of LEED. In particular, if the effect of green policies within adopting cities is mainly driven by unobserved (to the analyst) regulatory or zoning preferences for LEED projects, we would expect much smaller effects in neighboring non-adopting cities that presumably do not offer such preferences. Put differently, we are looking for evidence of spillovers, which should not stop at the city line.

We find a statistically significant increase of 0.9 private LEED registrations among neighbors relative to their matched controls (Column 4). When normalized by the baseline registration rate of 1.5 buildings per year, this translates to a marginal effect of 61 percent, which is somewhat smaller than the 90-percent marginal effect for green policy adopters (Column 1). Again, these results are robust to the omission of CEM weights and controls, as illustrated in Panel B. From these findings, we conclude that the link between government green building procurement policies and the private-sector adoption of green building practices is not solely due to preferential treatment of green buildings by city-level zoning or permitting officials. Instead, our results imply that these procurement policy effects reflect a spillover from green policy adopter cities to private developers in neighboring cities. This interpretation of the neighbor-city effects is also consistent with our finding (Column 5) that the number of government LEED registrations is significantly higher in neighboring cities that do not themselves adopt a green building procurement policy—but that might respond to the emergence of a LEED-based green building infrastructure—than in these neighboring cities' matched controls.

Finally, Column 6 in Table 3 presents weighted OLS estimates of the impact of being a green policy neighbor on the number of LEED Accredited Professionals. We find a statistically significant increase of 4.1 LEED Accredited Professionals, or roughly 56 percent of the weighted mean for controls. This suggests that the market for architects, contractors, consultants, and others with green building capabilities is regional, with spillover from policy adopters to neighboring cities helping to explain the statistically weaker impact of policy adoption on LEED Accredited Professionals in the policy-adopting cities themselves (Column 3). Put another way, the expected effect was there, but we had to look further afield to see it.

D. *Difference-in-Differences*

We now exploit the panel nature of our policy-adoption and outcome measures to estimate models that compare LEED diffusion in treatment and control cities before and after the adoption of a green procurement policy. Specifically, we estimate the following two-way fixed-effects model:

(2) $$Y_{it} = \alpha_i + \lambda_t + \beta\, GreenPolicyAdopted_{it} + \boldsymbol{\gamma} \cdot X_{it} + \varepsilon_{it},$$

where α_i is a set of city fixed effects that absorb all other time-invariant city-level covariates, λ_t is a set of year dummies, and X_{it} measures annual nonresidential construction starts in city *i* in year *t*. The coefficient β measures the impact of adopting a green building procurement policy on treated cities. We estimate the model by OLS (without weights), assuming that, within our matched sample, policy adoption is as good as randomly assigned after conditioning on city fixed effects (Heckman and Hotz 1989).

The results of these difference-in-difference models are reported in Table 4. The large, positive, and statistically significant estimates of β indicate a robust treatment effect for our main LEED adoption outcomes in both samples. We estimate an increase of 2.3 private LEED registrations per year in green policy adopters and 0.15 private LEED registrations per year in green policy adopter neighbors. We also find a statistically significantly increase of 11.0 LEED Accredited Professionals per year in the adopter cities and 1.2 per year in the neighboring cities.

In the bottom two rows of Table 4, we report F-tests of the null hypothesis that there is no difference in the trends of the outcome variable between treatment and control cities prior to the adoption of the green building procurement policy. To implement this test, we drop all observations where $GreenPolicyAdopted_{it}$ equals 1 from the estimation sample, add a new set of indicator variables that equal 1 *t* years before a city *i* adopts a policy (where t equals 1 through 4), and report an F-test for the joint significance of these pre-policy indicators. We find no evidence that private developers in green policy adopters had different LEED registration trends than private developers in the control cities. However, there is some evidence that local governments tried LEED before adopting the procurement policy and that real estate professionals in policy adopter cities were becoming LEED-accredited at a higher rate before the policies went into place.[29] We find no difference in the pre-adoption trends for any outcome in the policy adopter neighboring cities.

Since there is typically some public discussion prior to the adoption of a green building procurement policy, it is not especially surprising to find real estate professionals moving slightly ahead of the policy change. Indeed, our preferred interpretation of the results in Tables 3 and 4 is that municipal green building policies help solve the coordination problem among developers and complementary input suppliers by providing a highly visible source of demand for green building inputs. To provide further evidence for this interpretation, we turn to a set of analyses showing that the data do not support some of the alternative mechanisms discussed above.

E. *Awareness of LEED*

One alternative to our proposed mechanism is that developers, consumers, and input suppliers were unaware of LEED certification before their municipal government adopted a green building policy. This is a plausible story, particularly given the overall trend in LEED adoption depicted in Figure 1, which we take as evidence of increased awareness of the potential rents available to green development (Eichholtz, Kok, and Quigley 2012). If a combination of latent demand and increased awareness were driving our results, we would expect to see public green procurement policy having a larger impact in cities where there is a higher demand for other green amenities, since the publicity surrounding the municipal government's commitment would raise awareness of green building practices, which would stimulate private-sector adoption. We explore this idea by estimating cross-sectional OLS models that predict *Private LEED Registrations* based on interactions of a city's average preference for environmental amenities (*Prius Share* and *Green Ballot Share*) with *Green Policy Adopter*.[30]

The results in Table 5 show that private developers in cities with a greater share of Prius registrations or greater support for green ballot initiatives do not exhibit a stronger response to a

[29] Using an alternative hazard specification, we find no significant influence of either cumulative LEED registrations or cumulative LEED Accredited Professionals on the adoption of a government green building procurement policy (results available upon request).
[30] In each regression, we demean the continuous variable in the interaction, so the main effect of policy adoption can be interpreted as an average treatment effect on the treated.

public green procurement policy. While the *Prius Share* interactions are imprecise, the interactions with *Green Ballot Share* are essentially zero for the neighbor city sample. *LCV House Score* and *LCV Senate Score* also yielded precisely estimated zeroes on the interaction term (unreported). These results are robust to dropping the CEM weights and varying the set of control variables. Overall, the results in Table 5 suggest that the measured green procurement policy effects do not stimulate latent demand by making consumers, developers, and suppliers more aware of the possibility of LEED certification.

F. *Entry and Scale Economies*

A second alternative to the coordination mechanism that we emphasize is that government procurement simply increases demand to the point at which building industry professionals can recover the fixed costs of LEED accreditation. In this story, private-sector adoption follows because learning and increased competition drive down the price of green inputs closer to suppliers' average cost once a larger number of LEED Accredited Professionals have entered the local market.

One testable implication of the scale-and-entry-based explanation of our measured procurement policy effects is that the impact of municipal procurement policies should decline with city-size. Intuitively, private demand for LEED buildings is more likely to cover a supplier's entry costs in large markets, leading to robust competition among suppliers operating at efficient scale (Bresnahan and Reiss 1991). With competitive factor markets, the increased demand from a municipal procurement policy will have little or no impact on suppliers' average costs or the prices charged to a green building developer.

We examine the link between city-size and the impact of municipal green procurement policies by estimating cross-sectional OLS regression models of the number of LEED Accredited Professionals on two measures of market size (*Population* and *Total New Buildings*), each interacted with our two treatment dummies (*Green Policy Adopter* and *Green Policy Adopter Neighbor*). The results of these four models, reported in Columns 1-4 of Table 6, suggest that the impact of policy adoption on the number of LEED Accredited Professionals increases with city-size for policy-adopter cities and has no relationship to city-size among policy adopter neighbors.[31] These results are inconsistent with the hypothesis that government procurement policies promote entry in markets where limited private demand had been insufficient to convince real estate professionals and other input providers to invest in LEED-specific capabilities.

G. *Indirect Network Effects*

The results thus far measure the impact of government green procurement policy adoption on private-sector green building activity and on real estate professionals' investments in human capital for green building. Our findings are consistent with the explanation that green building procurement policies can break a deadlock among real estate professionals, who are reluctant to invest in LEED accreditation without evidence of demand, and building developers, who are reluctant to embark on building green until local real estate professionals have invested in acquiring expertise. However, we have not yet tried to measure the indirect network effects at the heart of this story; that is, the causal impact of LEED Accredited Professionals on LEED registrations and vice versa. Our theory that procurement policies help local markets overcome "excess inertia" requires both of these structural parameters to be positive.

Instrumental Variable Models—We use instrumental variables to estimate the indirect network effects. To identify the impact of the number of LEED-accredited professionals on the number of private LEED registrations, we require an instrument that is correlated with the supply of LEED Accredited Professionals but uncorrelated with unobserved drivers of private LEED registrations. We propose to use government green procurement policy adoption in "distant" cities as our instrument. Specifically, we use the log of the number of green policy adopter cities between 25 and 50 miles from the center of the focal city to instrument for the number of LEED Accredited Professionals in all cities within 25 miles of that focal city. This instrument is motivated by the assumption that markets served by building industry professionals are more dispersed than both the drivers of municipal procurement policy and the direct impact of green building procurement policies. Put differently, we assume that green building procurement policies in cities that are 25 to 50 miles away have no impact on developers of private buildings other than through the supply of LEED Accredited Professionals, which we view as a proxy for a

[31] Once again, the results are robust to dropping the CEM weights and varying the set of regression controls.

host of local green inputs.

Figure 3 provides some evidence that building industry professionals might transmit the impact of green building procurement policies over distances of 25 to 50 miles. It shows a histogram of the distance between architects' and general contractors' business locations and the project sites they work on, based on our McGraw Hill project-level construction starts data. The median distance between a project and a professional's office address is 28 miles; the 75th percentile of this distribution is roughly 75 miles.

To isolate the reverse relationship—the impact of the number of LEED registrations on the number of LEED Accredited Professionals—we require an instrumental variable that is correlated with the number of LEED registrations but uncorrelated with unobserved drivers of local real estate professionals' decisions to seek accreditation. Building on the instrumental variables strategy used in Corts (2010), we use *Total New Buildings* as an instrument for *Total Private LEED Registrations*. Intuitively, as the number of new building starts increases, so does the probability of having one or more LEED-registered projects that could stimulate investment among real estate professionals to become LEED Accredited Professionals. Moreover, since we condition on *Population* and *New Buildings*, the key assumption underlying the validity of our instrument is that variation in the *intensity* of development (that is, the number of buildings per capita within each city) between 2003 and 2007 will affect the number of private LEED registrations (for example, because of competition among developers) without otherwise altering the incentive for real estate professionals to seek LEED accreditation. Because the number of new buildings is clearly exogenous to an individual real estate professional's decision to seek LEED accreditation, the main concern with this instrument is that omitted variables might be correlated with both building activity and LEED accreditation rates. Thus, we continue to control for various city-level measures of green taste.

Instrumental Variable Results.—The estimation sample for our IV analysis includes all cities that did not adopt a green building procurement policy. All models control for *Population*, *Income*, *College*, *Prius Share*, and *Green Ballot Share*. Columns 1 and 2 of Table 7 report OLS and IV estimates of the impact of *Total LEED Accredited Professionals* on *Total Private LEED*

Registrations.[32] Column 1 reports OLS estimates of the correlation between the number of LEED Accredited Professionals in the cities within 25 miles of a focal city and the number of LEED registrations in that focal city. This correlation is statistically significant and suggests an increase of 0.14 private LEED registrations per log-point increase in the number of LEED Accredited Professionals in the surrounding cities. Column 2 presents our IV estimates, which use distant policy adoption as an instrument for the number of nearby LEED Accredited Professionals. The IV results show a very strong first-stage correlation between distant cities with green policies and LEED Accredited Professionals in the cities surrounding the focal city; the second-stage result indicates a significant positive impact of these nearby LEED Accredited Professionals on the number of private LEED registrations. While the IV estimate is very similar to our baseline OLS estimate, it is important to stress that our "excess inertia" hypothesis implies that LEED Registrations and LEED Accredited Professionals are simultaneously determined, and that the IV procedure isolates the response of LEED Registrations to an exogenous shift in the supply of Accredited Professionals. The IV estimates imply that adding seven LEED Accredited Professionals to nearby cities causes one additional LEED registration in a focal city. This strikes us as a plausible figure, particularly if we interpret the number of LEED Accredited Professionals as a proxy for other inputs, such as the availability of green building materials through local distributors.

Columns 3 and 4 of Table 7 examine the impact of the number of private LEED registrations on the number of LEED Accredited Professionals. OLS results are presented in Column 3 as a baseline. In Column 4, we use *New Buildings* as an instrument for *Private LEED Registrations*. Once again, we find a strong first-stage relationship and a positive impact of LEED building rates on the supply of LEED Accredited Professionals. In this case, the key coefficient increases by roughly 60 percent compared to the OLS correlation and a test of the null hypothesis that the number of LEED registrations is exogenous is rejected at the five-percent level ($p=0.01$).

Together, these IV results provide evidence of two positive causal relationships operating simultaneously: (1) an increase in the supply of LEED Accredited Professionals causes an

[32] We find somewhat larger effects for a sample of medium-size cities (20,000 to 800,000 residents) that did not adopt a green building policy. We also obtain estimates similar to those in Columns 2 and 4 of Table 7 if we estimate the full system of equations using generalized method of moments (GMM) estimation.

increase in the number of private LEED registrations and (2) an increase in the number of private LEED registrations causes an increase in the number of LEED Accredited Professionals. These indirect network effects are a necessary (though not necessarily sufficient) condition for the existence of a chicken-and-egg dilemma in the adoption of a new quality standard.[33] More generally, by showing how distant green procurement policies can influence local private LEED registration rates through the supply of nearby LEED Accredited Professionals, these results point to the importance of supply-side spillovers in the diffusion of LEED.

IV. Discussion and Conclusions

This paper provides evidence that public procurement policies can influence private-sector purchasing decisions in a way that reinforces underlying policy goals. Given the relative scale of public and private purchasing, such an effect might be a necessary condition for public procurement guidelines to have substantive impacts comparable to new laws or regulations.

While there is a substantial economic literature asking whether public investments "crowd out" private spending (e.g., Goolsbee (1998) on government R&D and Hoxby (1996) on public and private education), little research has examined whether or how government spending stimulates private-sector investment. We are aware of no prior study that examines whether or not government procurement acts as a focal adopter that tips the market towards a particular standard or certification scheme, despite this often being a primary stated objective of socially motivated government procurement policies such as "buy green" initiatives.

Our evidence of positive spillovers from public procurement is based on private developers adopting the LEED green building certification program following the enactment of public green building procurement policies—municipal bylaws that require public construction to follow green building practices. This is admittedly a case in which one might expect such reinforcing spillover effects, since LEED was rapidly emerging as the *de facto* standard for green building certification and many private developers could reasonably expect that green building would yield direct economic benefits in the form of energy savings and increased demand.

[33] Future work using a larger sample of cities might estimate a structural model that explicitly accounts for the possibility of multiple equilibria in the adoption process.

Moreover, governments are especially large customers in the construction services sector. Further research is needed to examine the extent to which public procurement rules influence private purchasing in mature markets in which governments account for a smaller share of total demand. Nevertheless, we find that a city with a municipal green building policy had roughly 90 percent more LEED registrations by 2008 than matched control cities of similar size, demographics, and tastes for environmentalism.

Another contribution of our study is to consider several mechanisms that might produce the private-sector spillovers discussed in the literature on government procurement, and to link these spillovers to the types of coordination problems studied in the industrial organization literature on platforms and compatibility standards (e.g., Farrell and Saloner 1986; Rysman 2009). In particular, we find evidence of an excess inertia or chicken-and-egg problem—a type of coordination failure typically associated with hardware-software platforms—in the diffusion of a new quality standard, and we show how this problem might be overcome if local governments step in as lead users.

Our analysis is subject to several caveats. First, despite our efforts to construct a well-matched control sample using the new methods developed by Iacus, King, and Porro (2012), one might still be concerned that our estimates are biased upwards if environmental preferences (beyond those we controlled for) are correlated with both municipal procurement policies and private-sector LEED adoption rates. However, we are somewhat comforted by finding similar "crowding in" effects in a sample of neighboring cities that had not themselves adopted green building policies. We also find no evidence of a divergence in LEED adoption between treated cities (either policy adopters or their neighbors) and their matched controls prior to the change in procurement policy. These findings provide evidence against stories of reverse causation or policy adoption by municipalities that are "captured" by greener elements of the real estate profession. Our preferred explanation for our main results is that green procurement policies had a combined effect that increased awareness of the LEED standard and fostered the development of complementary markets for specialized inputs, such as LEED Accredited Professionals.

As second caveat is that we do not measure the environmental impacts of increased LEED adoption (or even the final certification of all registered buildings). Engineering studies suggest that LEED certification is correlated with increased energy efficiency, but those estimates are based on data from a self-selected sample of LEED-certified buildings. Future research should examine the impact of public green building policies on environmental performance.

Finally, since our findings suggest that government procurement policies can catalyze the adoption of a privately developed certification scheme, one might ask whether governments typically choose the "right" standard? In the case of LEED, it is not clear whether (a) municipal green building policies promoted lock-in to a particular standard (the leading alternative was the EPA's Energy Star label) or (b) increasing returns simply led private and public actors to coalesce around the most popular measurement system at the time. Nevertheless, our LEED Accredited Professionals results show that government purchasing policies can promote standard-specific investments by various third parties, such as architects, contractors, and suppliers of green building materials. This both points to procurement policies as an effective policy tool and highlights the potential dangers of lock-in to a government-selected standard—particularly if it was developed by firms hoping to preempt more stringent regulation. The question of how government should be involved in the *ex ante* development of voluntary standards that might later provide the basis for procurement policies is an intriguing topic for future research.

References

Angrist, Joshua D., and Jörn-Steffen Pischke. 2009. *Mostly Harmless Econometrics: An Empiricist's Companion*. Princeton, NJ: Princeton University Press.

Bennear, Lori S., and Sheila M. Olmstead. 2008. "The Impacts of the 'Right to Know': Information Disclosure and the Violation of Drinking Water Standards." *Journal of Environmental Economics and Management* 56 (2): 117–130.

Brander, Luke, Xander Olsthoorn, Frans Oosterhuis, and Vivien Führ. 2003. "Triggering Innovation." In *Buying into the Environment: Experiences, Opportunities and Potential for Eco-Procurement*, edited by C. Erdmenger, 94–113. Sheffield, UK: Greenleaf.

Bresnahan, Timothy, and Peter Reiss. 1991. "Entry and Competition in Concentrated Markets." *Journal of Political Economy* 99 (5): 977–1009.

Chegut, Andrea, Piet Eichholtz, and Nils Kok. 2012. "Supply, Demand, and the Value of Green Buildings." Working Paper, European Center for Corporate Engagement. http://www.corporate-engagement.com/research/76.

Choi, Eugene. 2010. "Green on Buildings: The Effects of Municipal Policy on Green Building

Designations in America's Central Cities." *Journal of Sustainable Real Estate* 2 (1): 1−21.
Clinton, William J. 1998. "EPA Guidelines from Executive Order 13101." *Federal Register* 63 (179): 49643−49651, available at http://www.epa.gov/epp/pubs/13101.pdf.
Coggburn, Jerrell D., and Dianne Rahm. 2005. "Environmentally Preferable Purchasing: Who Is Doing What in the United States?" *Journal of Public Procurement* 5 (1): 23−53.
Commission of the European Communities. 2008. *Public Procurement for a Better Environment*. Brussels, July 16. Communication from the commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions.
Corts, Kenneth S. 2010. "Building Out Alternative Fuel Retail Infrastructure: Government Fleet Spillovers in E85." *Journal of Environmental Economics and Management* 59 (3): 219−234.
Delmas, Magali A., and Maria J. Montes-Sancho. 2010. "Voluntary Agreements to Improve Environmental Quality: Symbolic and Substantive Cooperation." *Strategic Management Journal* 31 (6): 576−601.
Doshi, Anil, Glen W. S. Dowell, and Michael W. Toffel. 2012. "How Firms Respond to Mandatory Information Disclosure." *Strategic Management Journal*, forthcoming.
Dranove, David, and Ginger Zhe Jin. 2010. "Quality Disclosure and Certification: Theory and Practice." *Journal of Economic Literature* 48 (4): 935−963.
Eichholtz, Piet, Nils Kok, and John M. Quigley. 2010. "Doing Well by Doing Good? Green Office Buildings." *American Economic Review* 100 (5): 2492−2509.
Eichholtz, Piet, Nils Kok, and John M. Quigley. Forthcoming. "The Economics of Green Building." *Review of Economics and Statistics*.
Environmental Law Institute. 2008. *Municipal Green Building Policies: Strategies for Transforming Building Practices in the Private Sector*. Washington, DC: Environmental Law Institute.
Farrell, Joseph, and Garth Saloner. 1986. "Installed Base and Compatibility: Innovation, Product Preannouncements, and Predation." *American Economic Review* 76 (5): 940−955.
Fetter, T. Robert, and Julie A. Caswell. 2002. "Variation in Organic Standards Prior to the National Organic Program." *American Journal of Alternative Agriculture* 17 (2): 55−74.
Fuerst, Franz, and Pat McAllister. 2011a. "Eco-Labeling, Rents, Sales Prices and Occupancy Rates: Do LEED and Energy Star Labeled Offices Obtain Multiple Premiums?" *Ecological Economics* 70 (6): 1220−1230.
Fuerst, Franz, and Pat McAllister. 2011b. "Green Noise or Green Value? Measuring the Effects of Environmental Certification on Office Values." *Real Estate Economics* 39 (1): 45−60.
Goolsbee, Austan. 1998. "Does Government R&D Policy Mainly Benefit Scientists and Engineers?" *American Economic Review* 88 (2): 298−302.
Green Building Certification Institute. 2011. "LEED for New Construction: Registering a Project." http://www.gbci.org/main-nav/building-certification/certification-guide/LEED-for-New-Construction/Project-Registration/registration.aspx.
Heckman, James J., and V. Joseph Hotz. 1989. "Choosing among Alternative Nonexperimental Methods for Estimating the Impact of Social Programs: The Case of Manpower Training." *Journal of the American Statistical Association* 84 (408): 862−874.
Hoxby, Caroline M. 1996. "Are Efficiency and Equity in School Finance Substitutes or Complements?" *Journal of Economic Perspectives* 10 (4): 51−72.
Iacus, Stefano M., Gary King, and Giuseppe Porro. 2012. "Causal Inference without Balance

Checking: Coarsened Exact Matching." *Political Analysis* 20 (1): 1−24.

Jin, Ginger Zhe, and Phillip Leslie. 2003. "The Effect of Information on Product Quality: Evidence from Restaurant Hygiene Grade Cards." *Quarterly Journal of Economics* 118 (2): 409−451.

Johnstone, Nick, ed. 2003. *The Environmental Performance of Public Procurement: Issues of Policy Coherence*. Paris: OECD Publishing.

Kahn, Matthew E. 2002. "Demographic Change and the Demand for Environmental Regulation." *Journal of Policy Analysis and Management* 21 (1): 45−62.

Kahn, Matthew E. 2011. "Do Liberal Cities Limit New Housing Development? Evidence from California." *Journal of Urban Economics* 69 (2): 223−228.

Kahn, Matthew E., and Ryan K. Vaughn. 2009. "Green Market Geography: The Spatial Clustering of Hybrid Vehicles and LEED Registered Buildings." *B.E. Journal of Economic Analysis & Policy: Contributions to Economic Analysis & Policy* 9 (2): 1−22.

Kim, Eun-Hee, and Thomas P. Lyon. 2011. "Strategic Environmental Disclosure: Evidence from the DOE's Voluntary Greenhouse Gas Registry." *Journal of Environmental Economics and Management* 61 (3): 311−326.

King, Andrew A., and Michael J. Lenox. 2000. "Industry Self-Regulation without Sanctions: The Chemical Industry's Responsible Care Program." *Academy of Management Journal* 43 (4): 698−716.

Kok, Nils, and Maarten Jennen. 2012. "The Impact of Energy Labels and Accessibility on Office Rents." *Energy Policy* 46: 489−497.

Kok, Nils, Marquise McGraw, and John M. Quigley. 2011. "The Diffusion of Energy Efficiency in Building." *American Economic Review* 101 (3): 77−82.

Lyon, Thomas P., and John W. Maxwell. 1999. "Corporate Environmental Strategies as Tools to Influence Regulation." *Business Strategy and the Environment* 8 (3): 189−196.

Marron, Donald. 1997. "Buying Green: Government Procurement as an Instrument of Environmental Policy." *Public Finance Review* 25 (3): 285−305.

Marron, Donald. 2003. "Greener Public Purchasing as an Environmental Policy Instrument." *OECD Journal on Budgeting* 3 (4): 71−105.

May, Peter J., and Chris Koski. 2007. "State Environmental Policies: Analyzing Green Building Mandates." *Review of Policy Research* 24 (1): 49−65.

McCrudden, Christopher. 2004. "Using Public Procurement to Achieve Social Outcomes." *Natural Resources Forum* 28 (4): 257−267.

Michelsen, Ottar, and Luitzen de Boer. 2009. "Green Procurement in Norway; A Survey of Practices at the Municipal and County Level." *Journal of Environmental Management* 91 (1): 160−167.

National Association of State Procurement Officials. 2010. "Green Purchasing Guidelines." http://www.naspo.org/content.cfm/id/green_guide.

National Association of State Procurement Officials and Responsible Purchasing Network. 2010. *Responsible Purchasing Trends 2010: The 'State' of Sustainable Procurement*. Oakland, CA: Responsible Purchasing Network.

Navarro, Mireya. 2009. "Some Buildings Not Living Up to Green Label." *New York Times*, August 30.

Newsham, Guy R., Sandra Mancini, and Benjamin J. Birt. 2009. "Do LEED-certified Buildings Save Energy? Yes, But…" *Energy and Buildings* 41 (8): 897−905.

Organisation for Economic Co-operation and Development. 2000. *Greener Public Purchasing: Issues and Practical Solutions*. Paris: Organisation for Economic Co-operation and Development.

Patrick, Deval L. 2009. "Executive Order No. 515 Establishing an Environmental Purchasing Policy." October 27. http://www.mass.gov/Agov3/docs/Executive%20Orders/executive_order_515.pdf.

Rader, Nancy. 1998. *Green Buyers Beware: A Critical Review of Green Electricity Products*. Washington, DC, Public Citizen.

Rainwater, Brooks. 2009. *Local Leaders in Sustainability: Green Building Policy in a Changing Economic Environment*. Washington, DC: American Institute of Architects. http://www.aia.org/advocacy/local/AIAB089213.

Reid, Erin M., and Michael W. Toffel. 2009. "Responding to Public and Private Politics: Corporate Disclosure of Climate Change Strategies." *Strategic Management Journal* 30 (11): 1157−1178.

Rochet, Jean-Charles, and Jean Tirole. 2006. "Two-Sided Platforms: A Progress Report." *RAND Journal of Economics* 37 (3): 645−667.

Rysman, Marc. 2009. "The Economics of Two-Sided Markets." *Journal of Economic Perspectives* 23 (3): 125−144.

Sabapathy, Ashwin, Santhosh K. V. Ragavan, Mahima Vijendra, and Anjana G. Nataraja. 2010. "Energy Efficiency Benchmarks and the Performance of LEED Rated Buildings for Information Technology Facilities in Bangalore, India." *Energy and Buildings* 42 (11): 2206−2212.

Siemens, Renetta. 2003. "A Review and Critical Evaluation of Selected Greener Public Purchasing Programmes and Policies." In *The Environmental Performance of Public Procurement: Issues of Policy Coherence*, 51−94. Paris: Organisation for Economic Co-operation and Development.

Sourani, Amr, and Muhammad Sohail. 2011. "Barriers to Addressing Sustainable Construction in Public Procurement Strategies." *Proceedings of the Institution of Civil Engineers (ICE)—Engineering Sustainability* 164 (4): 229−237.

Toffel, Michael W., and Jodi L. Short. 2011. "Coming Clean and Cleaning Up: Does Voluntary Self-Reporting Indicate Effective Self-Policing?" *Journal of Law and Economics* 54 (3): 609−649.

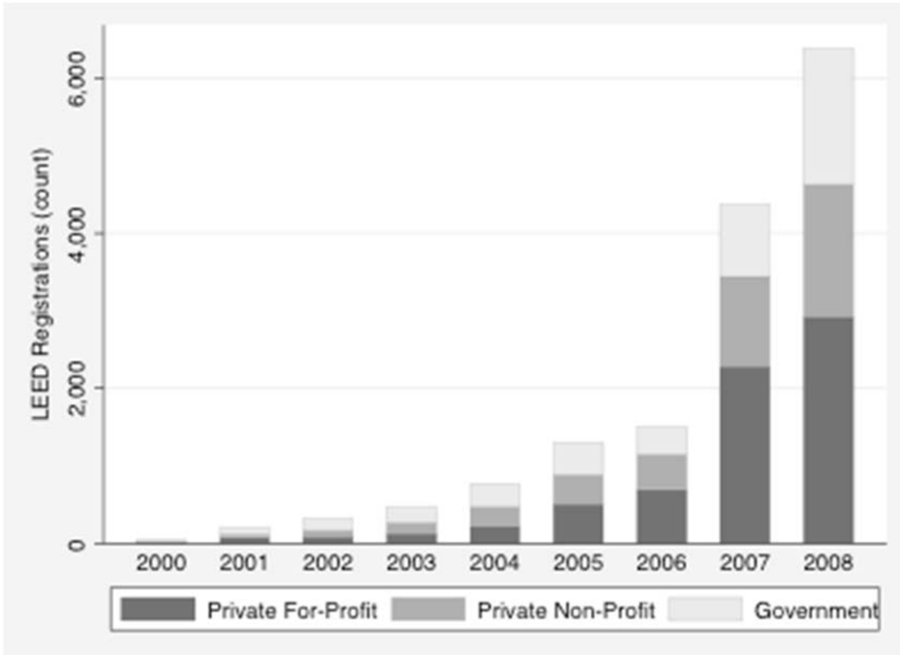
Turner, Cathy, and Mark Frankel. 2008. *Energy Performance of LEED for New Construction Buildings: Final Report*. White Salmon, WA: New Buildings Institute.

United Kingdom Office of Government Commerce. 2010. "Sustainable Procurement and Operations on the Government Estate: Government Delivery Plan Update—December 2009." http://www.ogc.gov.uk/documents/Delivery_plan_Dec09.pdf.

Weil, David, Archon Fung, Mary Graham, and Elena Fagotto. 2006. "The Effectiveness of Regulatory Disclosure." *Journal of Policy Analysis and Management* 26 (1): 155−181.

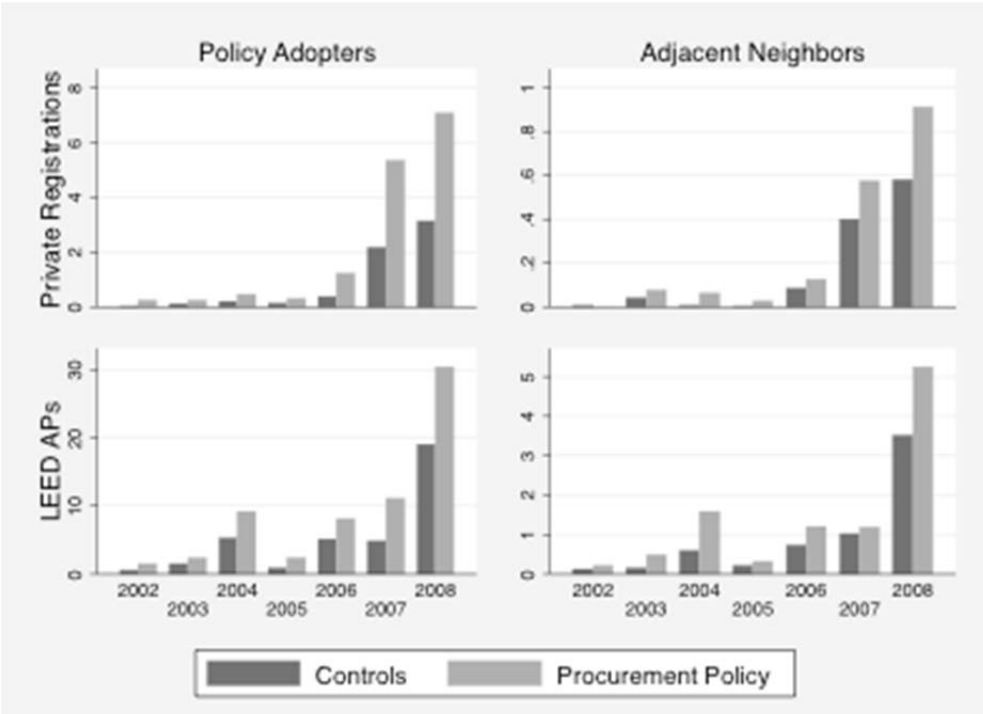
Wu, Xiaoyu, and Bowman Cutter. 2011. "Who Votes for Public Environmental Goods in California? Evidence from a Spatial Analysis of Voting for Environmental Ballot Measures." *Ecological Economics* 70 (3): 554−563.

Figure 1. Annual U.S. LEED Registrations by Type of Owner



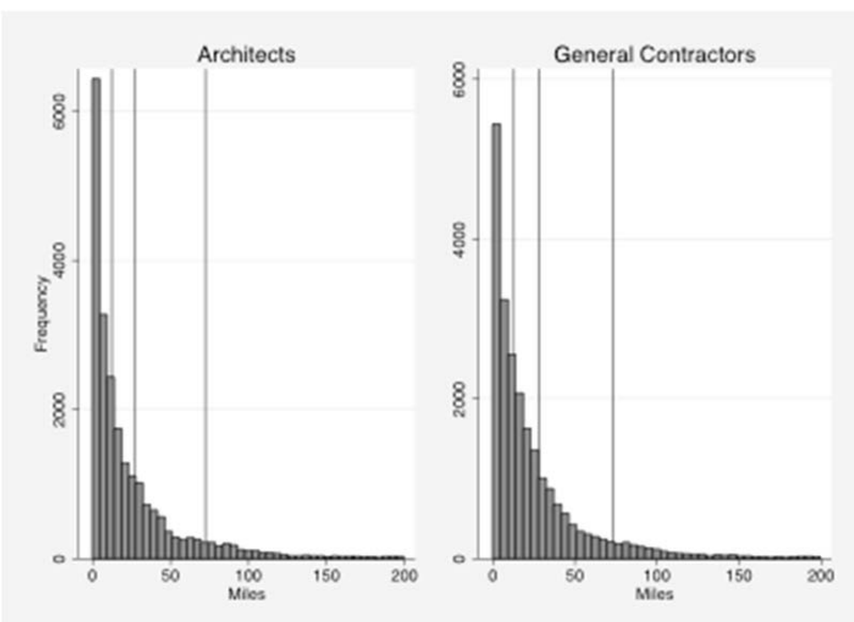
Notes: Graph is for all U.S. nonresidential new construction LEED registrations. Owner type codes provided by U.S. Green Building Council. Government includes federal, state, and local.

Figure 2. Mean LEED Registrations and Accreditations by Procurement Regime



Note: All figures are based on CEM-weighted annual means.

Figure 3. Geographic Agglomeration in Labor Markets for Real Estate Professionals



Notes: Distance from professional's address to building location based on great-circle calculations using Harvard Arc-GIS mapping software. Vertical bars represent 25th, 50th, and 75th percentile values in the empirical distribution of project-professional distances.

Table 1. Summary Statistics

Variable Name	Definition	Mean	SD	Min	Max
Panel A: City-level variables					
Total Private LEED Registrations	Total private LEED-registered buildings during 2001-08	1.93	6.25	0.00	99.00
Total LEED Accredited Professionals	Total LEED Accredited Professionals during 2001-08	7.51	27.38	0.00	416.00
Total Government LEED Registrations,	Total government LEED-registered buildings during 2001-08	0.29	0.94	0.00	12.00
Green Policy Adopter	City adopted green building policy by 2008 (dummy)	0.04	0.19	0.00	1.00
Green Policy Adopter Neighbor	City adjacent to a city that adopted green building policy by 2008 (dummy)	0.15	0.36	0.00	1.00
Prius Share	Toyota Prius as percent of all car registrations (x 100)	0.54	0.59	0.00	3.74
Green Ballot Share	Percent of votes in favor of green ballot measures	60.73	14.76	19.85	100.00
LCV Senate Score	State senator's League of Conservation Voters score	46.54	40.88	0.00	100.00
LCV House Score	State representative's League of Conservation Voters score	49.56	39.97	0.00	100.00
Population	City population (10,000s)	2.99	5.10	0.00	46.15
Total New Buildings	Total nonresidential construction starts during 2003-07	26.21	54.71	0.00	869.00
Buildings per Capita	New Buildings / Population	12.06	18.42	0.00	204.00
College	Percent college-educated	0.23	0.17	0.01	0.89
Income	Median household income	4.80	2.17	0.00	20.00
Panel B: City-year variables					
Annual Private LEED Registrations	New private LEED-registered buildings this year	0.20	1.32	0.00	52.00
Annual LEED Accredited Professionals	New LEED Accredited Professionals this year	0.04	0.24	0.00	6.00
Annual Government LEED Registrations	New government LEED-registered buildings this year	0.94	5.21	0.00	160.00
Green Policy Adopted	Focal city adopted policy by this year	0.02	0.13	0.00	1.00
Green Policy Adopted Neighbor	Neighbor city adopted policy by this year	0.09	0.29	0.00	1.00
Annual New Buildings	Nonresidential construction starts this year	26.21	54.68	0.00	869.00

Notes: Panel A provides summary statistics for a cross section of 735 California cities. Panel B reports annual variables at the city-year level. Both panels exclude Los Angeles, San Diego, San Jose, and San Francisco.

Table 2. Covariate Balance in Full and Matched Samples

	Panel A			Panel B			Panel C		
Sample	Full sample			Green policy adopter cities and matched controls			Green policy adopter neighboring cities and matched controls		
Weighting	No weights			Weighted			Weighted		
	Green policy adopters	All non-adopters	t-stat	Green policy adopters	Matched controls	t-stat	Green policy adopter neighbors	Matched controls	t-stat
Prius Share	0.93	0.53	3.62	0.86	0.80	0.41	0.71	0.72	0.05
Green Ballot Share	72.26	60.25	4.35	71.08	68.27	1.09	68.08	65.98	1.36
LCV Senate Score	68.69	45.58	3.00	68.96	60.85	0.81	66.98	65.47	0.27
LCV House Score	69.00	48.53	2.72	65.62	61.64	0.33	64.44	63.64	0.13
Population	14.36	2.53	13.68	13.70	13.51	0.06	3.86	3.71	0.33
Annual New Buildings	140.79	21.59	12.64	139.77	109.53	0.78	25.94	31.26	1.01
Buildings per Capita	10.62	12.20	0.45	10.83	9.98	0.49	10.22	9.73	0.25
College	0.35	0.22	4.09	34.53	34.17	0.10	31.06	29.85	0.39
Income	5.58	4.77	1.97	5.70	5.83	0.33	5.98	6.04	0.12
Cities	29	697		26	180		80	291	

Notes: Panel A reports means of each variable and t-statistic from unweighted OLS regression of the variable on *Green Policy Adopter* dummy. Panels B and C report CEM-weighted means of each variable and the t-statistic from CEM-weighted OLS regression of the variable on *Green Policy Adopter* dummy (middle panel) or *Green Policy Adopter Neighbor* dummy (right panel). CEM weights are described in Iacus, King, and Porro (2012) and discussed in the text.

Table 3. Effects of Green Building Procurement Policies on LEED Registrations and Accredited Professionals: Cross-sectional Regression Results

Sample	Green policy adopter cities and matched controls			Green policy adopter neighboring cities and matched controls		
Outcome	Total private LEED registrations	Total government LEED registrations	Total LEED Accredited Professionals	Total private LEED registrations	Total government LEED registrations	Total LEED Accredited Professionals
	Panel A: CEM-weighted OLS Regressions					
	(1)	(2)	(3)	(4)	(5)	(6)
Green Policy Adopter	7.46	1.59	15.74			
	[3.26]**	[0.53]***	[14.46]			
Green Policy Adopter Neighbor				0.95	0.23	4.05
				[0.39]**	[0.10]**	[1.84]**
CEM-weighted mean outcome	8.29	0.93	40.81	1.55	0.26	7.20
R-squared	0.56	0.34	0.37	0.28	0.13	0.41
	Panel B: Unweighted OLS Regressions					
	(7)	(8)	(9)	(10)	(11)	(12)
Green Policy Adopter	7.20	1.37	19.95			
	[2.62]***	[0.39]***	[10.94]*			
Green Neighbor Adopter Neighbor				0.94	0.22	3.86
				[0.37]**	[0.10]**	[1.60]**
Unweighted mean outcome	4.75	0.69	17.95	1.01	0.18	4.48
R-squared	0.64	0.47	0.59	0.36	0.20	0.38
Observations (Cities)	202	202	202	453	453	453

Notes: CEM-weighted OLS regressions with robust standard errors in brackets; *** p<0.01, ** p<0.05, * p<0.10. Models in Panel A include controls for *Prius Share*, *Total New Buildings*, *College*, *Income*, *Green Ballot Share*, *LCV Senate Score*, and *LCV House Score*. Unit of analysis is a city. (See Table 2 for the number of treated and control units in the matched samples.)

Table 4. Effects of Green Building Procurement Policies on LEED Registrations and Accredited Professionals: City Fixed-effects Regression Results

Sample	Green policy adopter cities and matched controls			Green policy adopter neighboring cities and matched controls		
Outcome	Annual private LEED registrations (1)	Annual government LEED registrations (2)	Annual LEED Accredited Professionals (3)	Annual private LEED registrations (4)	Annual government LEED registrations (5)	Annual LEED Accredited Professionals (6)
Green Policy Adopted	2.30	0.27	11.01			
	[0.78]***	[0.11]**	[3.64]***			
Green Policy Adopted Neighbor				0.15	0.03	1.16
				[0.07]**	[0.02]	[0.26]***
Observations (city-years)	1672	1672	1672	2968	2968	2968
Cities	209	209	209	371	371	371
Mean of outcome	0.50	0.09	2.22	0.10	0.02	0.56
R-squared	0.17	0.09	0.24	0.11	0.03	0.18
	F-test for pre-policy trend differences					
F-stat	0.52	2.30	2.39	0.96	0.51	1.78
P value	0.72	0.06	0.05	0.42	0.73	0.13

Notes: OLS coefficients, with robust standard errors (clustered on city) in parentheses; *** p<0.01, ** p<0.05, * p<0.10. Unit of analysis is a city-year. All regressions include city fixed effects and year fixed effects, control for *Annual New Buildings*, and do not include CEM weights.

Table 5: Effects of Green Building Procurement Policy Interacted with Green Demographics on LEED Registrations

Sample	Green policy adopter cities and matched controls		Green policy adopter neighboring cities and matched controls	
Outcome	Total private LEED registrations			
	(1)	(2)	(3)	(4)
Green Policy Adopter	6.95 [3.38]**	7.36 [2.97]**		
Green Policy Adopter × Prius Share	4.68 [5.24]			
Green Policy Adopter × Green Ballot Share		0.03 [0.33]		
Green Policy Adopter Neighbor			0.83 [0.34]**	0.79 [0.40]*
Green Policy Adopter Neighbor × Prius Share			0.50 [0.62]	
Green Policy Adopter Neighbor × Green Ballot Share				0.02 [0.04]
Observations (Cities)	206	206	371	371
R-squared	0.56	0.56	0.28	0.28

Notes: All models estimated with OLS using CEM weights. Robust standard errors in brackets; *** p<0.01, ** p<0.05, * p<0.10. Unit of analysis is a city. Additional unreported controls are *Prius Share*, *Green Ballot Share*, *LCV Senate Score*, *LCV House Score*, *Total New Buildings*, *Population*, *College*, and *Income*.

Table 6: Effects of Green Building Procurement Policy Interacted with City-Size on LEED Professional Accreditations

Sample	Green policy adopter cities and matched controls		Green policy adopter neighboring cities and matched controls	
Outcome	Total LEED Accredited Professionals			
	(1)	(2)	(3)	(4)
Green Policy Adopter	-2.78 [13.51]	-8.30 [11.03]		
Green Policy Adopter × Population	2.91 [1.27]**			
Green Policy Adopter × Total New Buildings		0.39 [0.08]***		
Green Policy Adopter Neighbor			3.44 [1.72]**	3.61 [1.56]**
Green Policy Adopter Neighbor × Population			0.39 [0.62]	
Green Policy Adopter Neighbor × Total New Buildings				0.05 [0.08]
Observations (Cities)	206	206	371	371
R-squared	0.42	0.48	0.41	0.42

Notes: All models estimated with OLS using CEM weights. Robust standard errors in brackets; *** p<0.01, ** p<0.05, * p<0.10. Unit of analysis is a city. Additional unreported controls are *Prius Share*, *Green Ballot Share*, *LCV Senate Score*, *LCV House Score*, *Total New Buildings*, *Population*, *College*, and *Income*.

Table 7: OLS and IV Estimates of Indirect Network Effects

Sample	All cities without green procurement policy			
Outcome	Total Private LEED registrations		Total LEED Accredited Professionals	
Estimation	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)
log(Total of LEED Accredited Professionals within 25 miles)	0.14 [0.06]**	0.17 [0.08]**		
Total Private LEED Registrations			2.17 [0.26]***	3.43 [0.49]***
	First-stage coefficients and statistics			
log(Number of cities with green policy within 25 to 50 miles in 2008)		1.29 [0.07]***		
Total New Buildings				0.05 [0.01]***
F-test of excluded IVs		322.11***		48.25***
Observations (cities)	697	697	697	697
R-squared	0.41	0.41	0.55	0.47

Notes: OLS and instrumental variable regressions with robust standard errors in brackets; *** p<0.01, ** p<0.05, * p<0.10. Unit of analysis is a city. All models include controls for *Prius Share*, *Green Ballot Share*, *Population*, *College*, and *Income*.

Appendix. California Cities with a Green Building Policy by 2008

	City	In matched sample	Population (10,000s)
1	Los Angeles	No	369.49
2	San Diego	No	122.34
3	San Jose	No	89.50
4	San Francisco	No	77.67
5	Long Beach	Yes	46.15
6	Sacramento	Yes	40.70
7	Oakland	No	39.95
8	Anaheim	Yes	32.80
9	Stockton	Yes	24.38
10	Fremont	Yes	20.34
11	Glendale	Yes	19.50
12	Santa Clarita	Yes	15.07
13	Santa Rosa	Yes	14.76
14	Irvine	Yes	14.31
15	Sunnyvale	Yes	13.18
16	Corona	Yes	12.50
17	Costa Mesa	Yes	10.87
18	Berkeley	No	10.27
19	Santa Clara	Yes	10.24
20	Ventura	No	10.09
21	Richmond	Yes	9.92
22	Santa Barbara	Yes	9.23
23	Santa Monica	Yes	8.41
24	San Leandro	Yes	7.95
25	Carlsbad	Yes	7.82
26	Livermore	Yes	7.33
27	Alameda	Yes	7.23
28	Temecula	Yes	5.77
29	La Mesa	Yes	5.47
30	Cupertino	Yes	5.05
31	West Hollywood	Yes	3.57
32	Dublin	Yes	3.00
33	Cotati	Yes	0.65